Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

EVALUATION OF EXPLODING WIRE TECHNIQUE AS A CALIBRATED ENERGY SOURCE FOR INITIATING EXPLOSIVES

E. Contestabile and E. Shimoon
Canadian Explosives Research Laboratory

April 1986

This document is an unedited interim report prepared primarily for [illegible] and does not represent a final evaluation of the opinion of the Canada Centre for Mineral and Energy Technology (CANMET)

Ce document est un rapport provisoire non-révisé et rédigé principalement pour fin de diffusion et de documentation interne. Il ne représente nullement l'opinion définitive du Centre canadien de la technologie des minéraux et de l'énergie (CANMET)

9 pp

MICROMEDIA
AUG 19 1988

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT
MINING RESEARCH LABORATORIES
DIVISION REPORT ACEA/MRL 86-44(TR)

EVALUATION OF EXPLODING WIRE TECHNIQUE AS A CALIBRATED ENERGY SOURCE FOR INITIATING EXPLOSIVES

by

E. Contestabile* and E. Shimoon**

ABSTRACT

This report presents preliminary data on an exploding wire technique as a calibrated energy source for the initiation of explosives.

*Explosives Scientist, Canadian Explosives Research Laboratory, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa.

**Civil Engineer, formerly Canadian Explosives Research Laboratory, Mining Research Laboratories, CANMET, Energy, Mines and Resources, Canada, Ottawa.

ÉVALUATION DE LA TECHNIQUE DU FIL EXPLOSANT EN TANT QUE SOURCE D'ÉNERGIE ÉTALONNÉE UTILISÉE POUR L'AMORÇAGE D'UN EXPLOSIF

par

E. Contestabile* et E. Shimoon**

RÉSUMÉ

Ce rapport présente les données préliminaires sur la technique du fil explosant en tant que source d'énergie étalonnée utilisée pour l'amorçage d'un explosif.

*Scientifique en matières explosives, **Ingénieur civil, ancien employé du LCRE, Laboratoire canadien de recherche sur les explosifs, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada.

TABLE OF CONTENTS

	Page
ABSTRACT	i
RÉSUMÉ	ii
INTRODUCTION	1
EXPERIMENT APPARATUS AND PROCEDURE	1
RESULTS	2
CONCLUSIONS	2
SUGGESTIONS FOR FUTURE WORK	4
REFERENCES	5

FIGURES

No.		
1.	Test circuit	1
2.	Test fixture	1
3.	Modes of wire disintegration	2
4.	Capacitance as a function of voltage for 50% energy levels	3
5.	50% energy levels as a function of the RC time constant	4

TABLES

1.	Electrical resistance of Nichrome V wire	1
2.	50% energy values required to explode the wire sample	2
3.	RC time constants for the 50% firing energy levels	3
4.	Sensitivity of the explosives tested to the number of grams of lead azide used as the initiating stimulus	3

EVALUATION OF EXPLODING WIRE TECHNIQUE AS A CALIBRATED ENERGY SOURCE FOR INITIATING EXPLOSIVES

INTRODUCTION

A study of exploding wires was begun with the aim that it could be used as a shock sensitivity test for explosives. Voltages in the neighbourhood of 30 kV are commonly used in this field of work. This preliminary test however, makes use of a low voltage (1 kV) power supply.

The discharge circuit used in exploding wire experiments requires a fast switch (i.e., SCR, thyrotron, spark gap) which has a large value of dI/dt required to handle the energy stored in the capacitor bank. For the purpose of evaluation, however, a simple solenoid activated bar switch was used in this work.

A variety of wire thicknesses were experimented with. The results presented in this report are on Nichrome V wires having diameters of 0.076 mm, 0.102 mm, and 0.203 mm. The melting point of this wire is about 1400°C and over the temperature range of (0-1000)°C, the resistance varies by 10%. Results of 50% energies required for exploding these wires are reported.

The criteria used for determining whether an explosion took place was based strictly on the noise produced and the visual effect.

EXPERIMENT APPARATUS AND PROCEDURE

The circuit used in this work is shown in Fig. 1. The power supply can be adjusted from 100 V to 1000 V while the capacitance is also variable within the limits of eight, 2000 microfarads capacitors.

The wire test sample was mounted across the terminals of the apparatus shown in Fig. 2, to maintain a constant length for each sample. An up-and-down method was used to determine the 50% energy required to explode the wire. In this process, the capacitance value was fixed and the voltage was varied in 5 V steps.

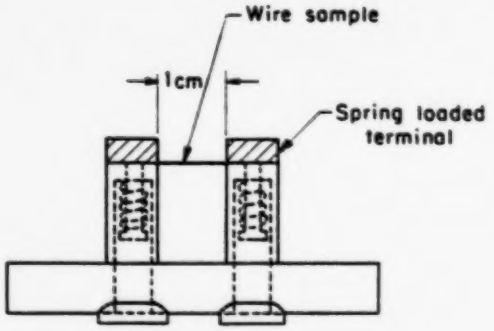


Fig. 2 - Test fixture

Table 1 summarizes the properties of the wire used. All the wires were tested in the 1 cm configuration. However, wire No. 1 was also tested in a 2 cm length with the 250 microfarad capacitance. Before placing the wire samples in the holder, they were inspected for scratches, kinks, and other deformaties. This assembly was then placed in a steel tank, remote from the firing circuit and observations were made from a window in the tank wall.

Table 1 - Electrical resistance of Nichrome V wire

No.	Dia (mm)	Resistance (ohms/cm)
1	0.076	2.970
2	0.102	0.820
3	0.203	0.217

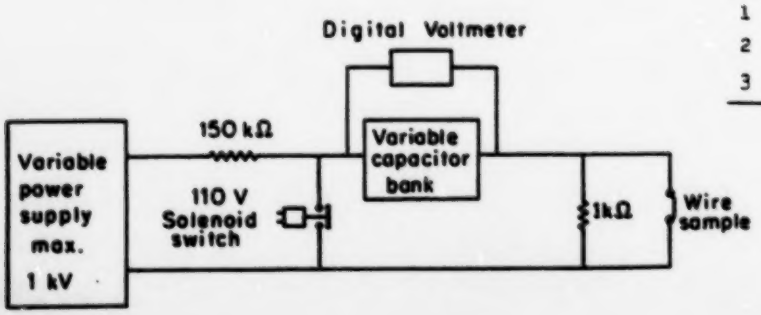
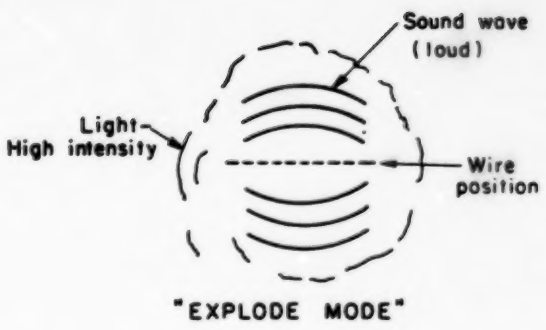


Fig. 1 - Test circuit

Once the sample was in place and the tank door shut, the capacitors were allowed to charge to the required voltage, at which time the solenoid switch was closed. The capacitors were fully discharged and shorted before entering the tank to inspect the results of the test. If the wire exploded, it emitted a sharp sound similar to that of a blasting cap. However, the wire could have also simply heated and remained intact or it may have "fused". The "explode" mode and "fuse" mode are both shown in Fig. 3.



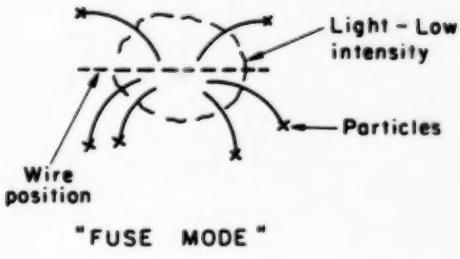


Fig. 3 - Modes of wire disintegration

RESULTS

The results from this preliminary work are presented in Table 2. From these data and that shown in Table 3, it was possible to plot the graphs shown in Fig. 4 and 5. The energy, E, in Joules (J) is calculated from the equation $E = 0.5\ CV^2$, where C is the capacitance and V is the voltage that the capacitors were charged to.

Using small cylindrical plastic cups as containers, several primary explosives were initiated with the exploding wires. The exploding wire was placed on the 1 cm diameter of the cup and centred in the explosive sample. The explosives tested were PETN, RDX, and HMX. All these samples were initiated within the energy testing levels presented above. Their relative sensitivity coincided with that obtained with lead azide (1) as an initiator and are listed in Table 4.

CONCLUSIONS

With the present circuit it was possible to obtain 50% firing energy levels in the range from 5 to 23 J for the wires tested. Figure 5 shows that it is possible to obtain fires on either side of the minimum 50% firing voltage by

Table 2 - 50% energy values required to explode wire

		Sample					
		1		2		3	
Test No.	Capacitance (uF)	Voltage (V)	Energy (J)	Voltage (V)	Energy (J)	Voltage (V)	Energy (J)
1	250	250	7.81	275	9.45	425	22.6
2	333	200	6.66	225	8.43	350	20.4
3	500	165	6.81	175	7.66	275	18.9
4	667	130	5.64	140	6.54	225	16.9
5	1000	105	5.51	100	5.00	150	11.2
6	1500	125	5.86	115	9.92	145	15.8
7	250	305	11.6	(2 cm long sample)			

Table 3 - RC time constants for the 50% firing energy levels

Sample No.	Capacitance (uF)	RC (us)	Voltage (V)	Energy (J)
1	250	742	250	7.81
	333	989	200	6.66
	500	1485	165	6.81
	667	1981	130	5.64
	1000	2970	105	5.51
	1500	4455	125	5.86
2	250	205	275	9.45
	333	273	225	8.43
	500	410	175	7.66
	667	547	140	6.54
	1000	820	100	5.00
	1500	1230	115	9.92
3	250	54	425	22.6
	333	72	350	20.4
	500	108	275	18.9
	667	145	225	16.9
	1000	217	150	11.2
	1500	326	145	15.8

Table 4 - Sensitivity of the explosives tested to the number of grams of lead azide used as the initiating stimulus

Explosive sample	Sensitivity to initiation
PETN	0.03
RDX	0.05
HMX	0.30

varying the capacitance. In doing so, however, one varies the RC time constant. Both Fig. 4 and 5 show that the curves are not symmetrical about the axis through the minimum. Also, from Fig. 4, the RC value seems to have little effect on the energy required to explode the thin (0.076 mm) wire, while its effect on the larger diameter wires is more pronounced. The same graph shows that the minimum energy required to explode a wire is best defined for the larger diameter wires.

The 50% firing energy does not appear to double as the length of wire is doubled. However, these apparent results do not include losses in the circuit. Therefore, the only statement that can be made is that as the wire length and diameter are decreased, the minimum energy required to explode the wire decreases.

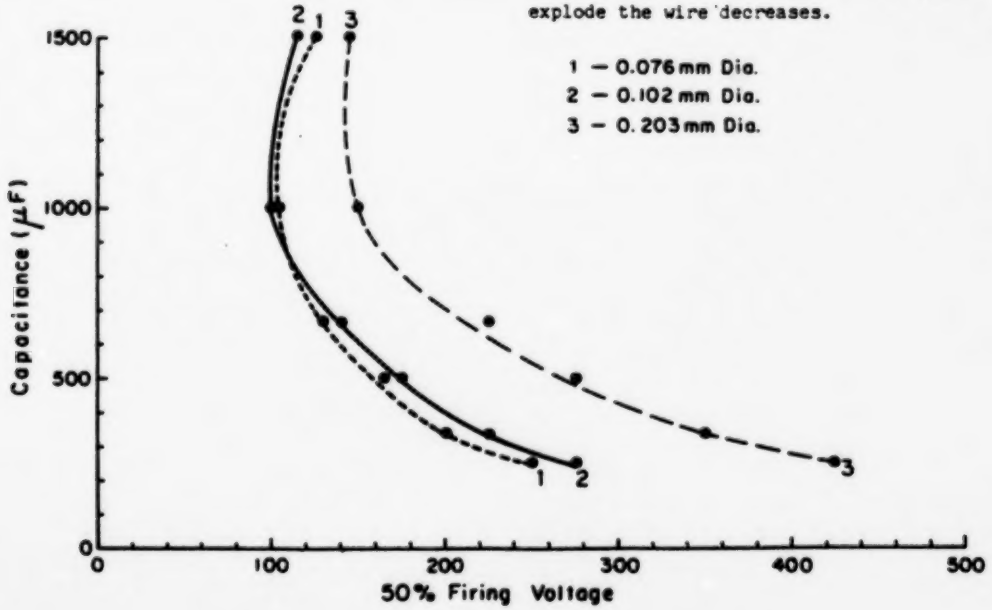


Fig. 4 - Capacitance as a function of voltage for 50% energy levels

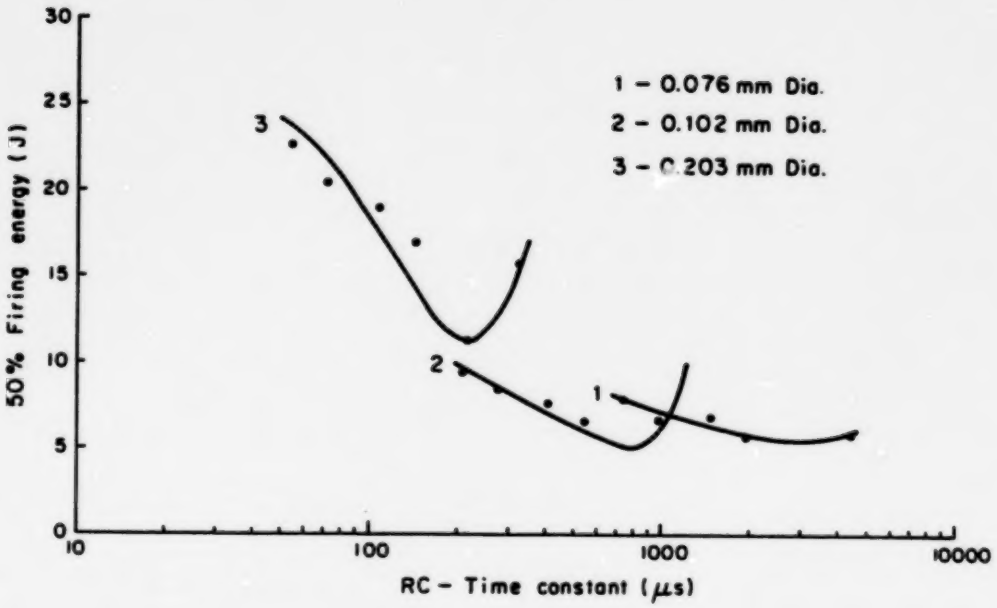


Fig. 5 - 50% energy levels as a function of the RC time constant

It should be noted that, due to the fact that a mechanical switch was used, it was impossible to make very accurate measurements. For example, the closing of the switch is accompanied by arcing so that the switch closing time is difficult to define. The arcing adds a time varying impedance to the circuit which is soon followed by ringing due to the switch terminals making contact.

The work done with exploding wires as initiators, points to the potential use of such an apparatus for determining minimum initiation energy for explosive and pyrotechnic substances.

SUGGESTIONS FOR FUTURE WORK

1. A similar circuit with a fast, low noise switch would allow accurate measurement of the critical energy.
2. A little work with metal foils has shown them to be efficient shock sources. More work on this type of sample should be pursued.
3. Once this apparatus has been perfected to the point where the critical energy to explode foils can be accurately measured, it should be applied as a shock sensitivity test on explosive and pyrotechnic substances.

REFERENCES

1. "Properties of explosives of military interest"; AMC Pamphlet No. 706-177, Headquarters, U.S. Army Materiel Command, Washington, DC, 20310.

2. Logan, J.D., et al., "Calculation of heating and burst phenomena in electrically exploded foils"; J Appl Phys 48:2; 1977.

3. Duchane, D.V. and Sacks, R.D. "Preparation and characterization of thin metal films for exploding-conductor excitation"; Analytical Chemistry 50:13; 1978.

4. Litvinenko, V.P. and Koval, S.V. "Correlation of the electrical and space-time characteristics during electrical explosion of wires, Sov Phys Tech Phys 28:4; 1983.

5. Strachan, D.C. "Categorizing exploding-wire discharges for use in detonation studies"; Combustion and Flame Vol. 36; 1979.

6. Jones, D.L. and Earnshaw, K.B. "A wire exploder for generating cylindrical shock waves in a controlled atmosphere"; National Bureau of Standards Technical Note 148; 1962.

7. Bennet, F.D., Burden, H.S. and Shear, D.D. "Correlated electrical and optical measurements of exploding wires"; Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, Report No. 1133; 1961.